CROP COEFFICIENT, YIELD RESPONSE OF COWPEA UNDER GRAVITY DRIP IRRIGATION SYSTEM WITH MULCH

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ABSTRACT

In the northwestern region of Nigeria, Samaru, Zaria, a season experiment was conducted to estimate yield response to water stress and derive the crop coefficient of cowpea using the single crop coefficient approach with a gravity drip irrigation system and mulch. The treatments comprised three levels of water application depths (50, 75, and 100% soil moisture deficit (SMD) and three types of mulching (Black polythene mulch (BPM), Rice straw mulch (RSM), and no-mulch (NM)}. The treatments were laid out in randomized complete block design (RCBD) and replicated three times. The result obtained from the research showed that the highest seed yield of 1499.8 kg/ha was obtained when the cowpea crop was irrigated at 75% soil moisture deficit with black polyethylene mulch (I75BPM). The lowest yield of 800.4 kg/ha was obtained when irrigation was done at 50% SMD and no mulch (I50NM). The highest seasonal water use was obtained at I100NM with 242 mm and the least is at I50BPM with 120 mm. The highest irrigation water applied is at I100NM with 283.15 mm and the least is at I50BPM with 133 mm. The crop response factor (Ky) values obtained were 0.83 for NM, 0.80 for RSM, and 0.79 for BPM. The crop coefficient factor (Kc) values range from 0.28-0.71 for initial stage, 0.36-0.97 for development stage, 0.27- 0.64 for mid-season stage, 0.23-0.58 for harvesting stage. The seasonal yield response to water stress as indicated above shows that cowpea exhibits a moderately sensitive and linear response to water stress. The results suggest that cowpea is likely to give significantly higher grain yield when a nearly optimal water supply is provided with Black polythene at 75% of soil moisture deficit.

1. INTRODUCTION

The erratic rainfall patterns in Nigeria are one of the major reasons for food scarcity (Nnadi et al., 2019). Cowpea is a staple food crop and a primary source of protein and fiber for most Nigerians. Its production is critical for national food security especially during dry seasons to complement what is harvested during the rainy season.

Cowpea is adapted to dry land farming in Nigeria and is considered a drought-resistant crop. Despite its adaptation to dry land conditions, one of the major yield-limiting factors in cowpea production is water shortage. Increasing the on-farm efficiency of rainwater not only for the smallholders who grow it but would also improve food security in the whole country and bring in revenue from export sales.

In order to increase the irrigation area coverage, there is need to increase the source of irrigation water supply and/or to improve the productivity of the irrigation scheme. The latter is better under the present condition because water management has become a problem as the farmers do not know enough about cowpea's water productivity. As water scarcity demands the maximum use of every drop of water, there is a need to calculate the water productivity of crops (Pereira et al., 2002; Bessembider et al., 2005; Fereres and Soriano, 2007).

Enhancing water use efficiency in irrigated agriculture includes increasing output per unit of water, reducing water loses and prioritizing water allocation (Igbadun and Oiganji, 2012; Howel, 2001). The sustainable use of water has to consider maximizing yield per unit of water rather than maximum yield per unit of area (Feeres and Soriano, 2007).

The objectives of this paper are to determine yield responses and derive the crop coefficient of cowpea under deficit irrigation with mulch materials under drip irrigation system.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

2.1.1 Location

Field experiment was conducted between 16th February to 2nd May, 2015/2016 dry season at the Department of Agricultural and Bio-resources Engineering Irrigation Experimental Field, Ahmadu Bello University, Zaria. It lies on latitude 11^0 11 'N, longitude 7°38'E, and altitude 686 m above mean sea level in the northern guinea savannah ecological zone of Nigeria with a semi-arid climate. The Mean annual rainfall of the study area is reported to be 1015.9 mm with an onset and cessation of rainfall as 21st May and 7th October respectively. The mean maximum air temperature is 29.7°C while the mean minimum air temperature is 13.3°C.

2.2 Soil Data Analysis

The physical characteristics of the experimental soils were determined at depths of 0-15 cm, 15- 30 cm and 30 – 45 cm, 45 – 60 cm, 60 – 75 cm using (hydrometer and pressure plates) the hydrometer method is for determination of soil particle size distribution and water retention with pressure plate apparatus (Galvak et al., 2005). The soil physical characteristics of the experimental plot showed the top soil to be loam with 1.82 g/cm^3 bulk density and underlined by clay loam (15-45 cm) with an average bulk density of 1.54 g/cm^3 as obtained from Soil Science Departmental Laboratory at Ahmadu Bello University, Zaria.

2.3 Treatment and Experimental Design

The experiment consisted of two factors namely: Irrigation at three (3) levels (50%,75% and 100% of Soil Moisture Deficit (SMD)) and three types of mulching materials (No mulch, rice straw and black polythene mulch) giving a total of a 9 treatments laid in Randomized Complete Block Design (RCBD) with three replications.

2.4 Test Crop

Sampea 8: The variety was obtained from seed processing Unit of Institute for Agricultural Research, Samaru, Zaria. It has a semi-erect growth habit, early maturing (60 – 65 days), medium white seeds with yield potential of 1200 $kgha^{-1}$ it has some level of resistance to insects and diseases.

2.5 Cultural Practices

The experimental fields were cleared, harrowed and made into ridges to create a favourable condition for seed establishment, and a distance of 0.75 m between rigdes and 1m between blocks. The field was marked into three (3) plots and nine (9) laterals per replication, with a total of 27 laterals.

The seeds were sown manually at three seeds per hole with an inter-row and intra-row spacing of 75cm and 30cm respectively at the rate 25 $kgha^{-1}$ (reason for change in conventional spacing is due to the emitter design spacing). After germination seedlings were thinned to two plants per stand 10 days after emergence. Fertilizer was applied using 100kg of compound fertilizer (N.P.K 20-40-20) per hectare and 30 kg SSP (Dugje *et al.*, 2009).The fertilizer was applied during planting of the seeds. Pre-emergency herbicide (gramazone) was used to kill the weeds on the day of planting. Thereafter weeding in the plots was done manually with hoe which was carried out two times two weeks and four weeks respectively after planting.

Prior to planting, soil moisture content at depths up to 20 mm were determined using the gravimetric method and one irrigation applied to raise the moisture content of the soil one day before planting to field capacity level., Full irrigation to restore soil moisture content to field capacity based on effective rooting depth of 5 cm, was given to all treatment plots for 10 days. The uniform application of water was done to ensure the crop is properly established before imposing the treatments.

The mulch materials were placed two weeks after planting. The polyethylene material (black) were cut to size and placed over the ridge. Holes were created in accordance with the plant spacing and the cowpea seedlings were passed through the holes carefully. The thickness of the polyethylene measured with a micrometre screw gauge was about 2 mm. The average weight of rice straw mulch spread in each of the plot with such treatment was 60 kg/ha of rice straw mulch was applied uniformly on each plot according to treatment description.

There was incidence of Aphis*(craccivora)* at about 4 weeks after planting, which was managed with the application of "sharp shooter*"(projenofos 40% + cypermethrin 4% E.C)* at 0.81itre/ha using 40 ml in 15 liters' knapsack sprayer as recommended by Avav and Ayuba (2006). Insect pests were controlled at 2 weeks after sowing, pre-flowering, flowering and podding stages. The crops were sprayed using Lara Force, with an active ingredient Lambda-cyhalothrin 25% EC. Hundred mils of insecticides was mixed with 16 liters of water and sprayed while fungal diseases were controlled using Benomyl as benated (50WP). Rabbit is another pest that affected the crop at the pod formation stage; this was properly managed traditionally by the use of local traps. The harvesting of the dried pods started 5 weeks after sowing. Picking was carried out three times at an interval of two weeks, this was carried out by hand–picking when the pods were fully matured and dried. All the net plots were harvested separately. Harvested pods were sun dried before threshing and the threshed seeds were further dried in the sun before weighing. The grain weight per each net plot was weighed and converted to grain yield in kilogram per hectare (kg/ha).

2.6 Soil Moisture Determination

Soil moisture content was monitored throughout the crop growing seasons with ML3 Theta Probe (Delta –T devices, London). The Theta Probe measures moisture content in-situ and expresses the volumetric soil moisture regime. Soil moisture measurement through the soil profile was done a day after an irrigation and before next irrigation at incremental depth of 0-15, 15-30, 45-60, 60-75 cm. 5 nos of 7.2 cm diameter PVC pipes were installed to the depths mentioned above in each plot. The pipe provides access for inserting the theta probe into the soil. Soil moisture measurement was made by inserting the sensing head of the theta probe into the soil through the access pipes to the various depths required below the soil surface.

2.7 Water Source

Surface runoff harvested from departmental drainage channels and stored in a 50 m^3capacity underground sump, 6 m deep, was the main source of the irrigation water. The sump water was recharged daily from the university water supply. A 2 horse power petrol engine pump was used to lift water from the underground tank to the elevated tanks, 2 m above ground which was placed on a concrete stand. When water has been pumped to the full capacity in tank A, the valve at the junction of pipe that supply water to tank A is closed. Valve at the junction that supply water to tank B is then opened until tank B is filled to capacity. Tank B supplies water to plots 2 and 3.

2.8 Drip System Components

Water from the elevated tanks release into a supply line 20 mm diameter, 5 m long made from Low Density Polyethylene Pipe (LDPEP). A ball valve and a primary filter are fixed on the line and it terminated at a 20 mm, 19 m long mainline of the same material. Four sub- mainlines each 180cm long, and 20 mm diameter was connected to the mainline. There were 27 laterals altogether installed. The hydraulic characteristics of the system installed that were evaluated included: emitter flow rate, emitter flow rate variation, uniformity coefficient and emission uniformity.

Table 1. Experimental Treatments and their Description

Treatment No	Treatment combinations	Description of treatment combinations
1.	I_{100}NM	Water application depth of 100% of SMD at, no mulch.
2.	I_{75}NM	Water application depth of 75% of SMD, no mulch
3.	I_{50}NM	Water application depth of 50% of SMD, no mulch
4.	I_{100}RSM	Water application depth of 100% of SMD, with rice straw mulch.
5.	I_{75}RSM	Water application depth of 75% of SMD with rice straw mulch.
6.	I_{50}RSM	Water application depth of 50% of SMD with rice straw mulch.
7.	I_{100}BPM	Water application depth of 100% of SMD with black polythene mulch.
8.	I_{75}BPM	Water application depth of 75% of SMD with black polythene mulch.
9.	I_{50}BPM	Water application depth of 50% of SMD with black polythene mulch.

Plates 1.1 and 1.2 are the layout of the laterals before planting operation.

1.1 Field Layout with Drip Laterals Component of the System

1.2 Hydraulic Evaluation of Drip System Layout

2.9 Data Collection Procedures

Measurement of emitter discharges were carried out from nine drip tubes randomly selected from each of the three junctions. In each drip tube five emitters were randomly selected from each quarter of the lateral length, giving a total of twenty emitters per drip tube. A total of one hundred and eighty emitters were tested in this research. Water cans were placed below the tubes to collect water dripping from the designated emitters over a given time. The water collected in each can was measured using a graduated cylinder; each emitter discharge measurement was replicated three times. The water temperature at the time of measurement was between 30°C and 38.5°C. The pressure heads at the upstream and downstream ends of the drips were measured using Pilot tube in the designated laterals.

The operating pressure was monitored using the Pitot tube to ensure that the pressure remained constant during each set of measurements. Emitter discharge was measured over a range of pressures because the junctions to which the laterals/drip tubes were connected were at different elevations along the sub-main in the experimental field.

2.10 Computation of emitter flow variation (Q_{var})

This was obtained as (Solomon, 2000):

$$Q_{var} (\%) = 100 \left(\frac{qmax - qmin}{qmax}\right) \quad (1)$$

where,

Q_{var} =emitter flow variation

q_{max} = maximum emitter flow along the lateral line (1/hr)

q_{mm} = minimum emitter flow along the lateral line (1/hr)

2.11 Computation of emission uniformity (EU)

$$EU=100(q_{iq}q/q) \quad (2)$$

where,

$q_{iq}q$= Average rate at low quarter (25%) of emitter discharge observations (1/hr.)

q = Average discharge rate of all observations (1/hr)

2.12 Wetting Diameter

One hour after irrigation, the diameter of the soil wetted by each emitter was measured using a ruler. It was found to be 17cm in diameter.

2.13 Computation of Coefficient of Variation

$$CV=\frac{Sq}{Qave} X\ 100 \quad (3)$$

where,

CV=Coefficient of Variation

Sq = standard deviation of discharge

q_{ave} = average discharge

2.14 Computation of Total Available Water

Michael (1978) gave the formula for determining Total Available Water (TAW) as:

$$TAW= \left(\frac{FC-PWP}{100}\right).Dz \quad (4)$$

where,

TAW = Total available water (mm)
Dz = depth of root zone (mm)
FC= field capacity (% weight)
PWP = Permanent wilting point (%weight)

According to Hune (2009), in drip irrigation, runoff, deep percolation and ground water contribution are all negligible because water is applied to the soil at and within the root zone at an application rate less than the soil infiltration rate. Therefore, the actual crop evapotranspiration between irrigations will be determined on the basis of change in mean value of soil water storage at 15cm incremental soil depth, from the day of irrigation, when the soil will be raised to the upper volumetric limit at which irrigation levels will be based to a day before the next irrigation. Now the actual crop evapotranspiration will be calculated as (Micheal, 1978):

$$ETa=\sum_{i=1}^{n} \frac{(MCa-MCb)}{t}Dz \quad (5)$$

where,

Eta = Actual crop evapotranspiration
M_{Cb} = Moisture content before irrigation (m^3/m^3)
M_{Ca} = Moisture content after irrigation (m^3/m^3)
t = Number of days since last irrigation to the day of sampling
N = number of soil layers.

2.15 Computation of Yield Response Factor to Water Deficit

This was obtained as Doorenbos and Kassam (1979):

$$1-\frac{Ya}{Ym} = Ky\left(1-\frac{ETa}{ETm}\right) \quad (6)$$

where,

Ya and Ym are the actual and maximum yield in kg/ha, respectively.

ETa and ETm are the actual and maximum evapotranspiration in mm, Ky is the yield response factor representing the effect of a reduction in evapotranspiration on yield reduction.

2.16 Statistical Analysis

The data collected were subjected to analysis of variance using SAS (9.0). Treatment mean were compare using LSD at 5% level of probability.

3. RESULTS AND DISCUSSION

3.1 Irrigation Water Applied and Seasonal Water Use

Table 2 shows the variation of water application depth along the growing season for the tested rates of water deficits. The table illustrates that, water application depth, for all treatments, took the same trend along the growing season, but with lower values according to the percent of water deficit. The figures also show that, water application depth for each treatment no matter the types of mulch material used had significantly affected availability of moisture to the crop. Irrigating at 100% of soil moisture depletion (SMD) with mulch (BPM) gives lower moisture depletion from the soil which is in line with Othman (2007) who reported on soil moisture conservation by mulch**.**

Table 2. Irrigation Water Applied (mm) for Cowpea during 2016 dry Season

Treatment	I_{100} RSM	I_{100} BPM	I_{100} NM	I_{75} RSM	I_{75} BPM	I_{75} NM	I_{50} RSM	I_{50} BPM	I_{50} NM
17/2/2016	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
21/2/2016	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
25/2/2016	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
29/2/2016	9.7	6.8	16.0	5.2	5.0	6.2	3.2	4.5	10.0
03/3/2016	9.8	7.0	16.1	5.9	6.3	6.9	3.4	4.6	10.9
07/3/2016	10.9	9.2	17.3	5.2	9.0	10.2	3.6	3.8	5.2
11/3/2016	10.9	9.8	17.3	6.0	8.9	9.0	4.2	3.4	5.4
16/3/2016	14.6	9.0	21.0	4.2	8.0	11.1	6.2	5.1	6.7
28/3/2016	14.9	9.3	22.5	4.5	8.2	11.2	6.8	6.0	6.8
31/3/2016	16.1	12.0	18.0	9.1	9.0	12.4	7.5	7.2	7.1
04/4/2016	16.3	13.9	18.2	10.0	6.3	12.3	7.0	7.6	6.4
08/4/2016	15.2	14.1	17.1	10.2	7.2	10.5	8.1	5.3	10.0
12/4/2016	9.5	15.0	17.2	9.7	5.2	11.0	7.0	5.4	9.0
16/4/2016	9.2	9.0	17.2	5.7	4.7	10.9	3.8	4.8	6.8
20/4/2016	7.2	9.9	17.6	5.2	4.5	10.9	3.6	4.9	7.2
24/4/2016	7.0	5.1	14.0	5.3	4.6	6.0	3.4	3.2	9.9
28/4/2016	6.5	6.1	14.5	7.7	4.3	6.3	3.2	3.4	6.1
02/5/2016	5.0	5.1	6.2	4.3	2.9	3.9	2.6	2.8	3.1
Total	**223.95**	**202.3**	**311.15**	**159.2**	**155.1**	**199.8**	**134.6**	**133**	**168.6**

Table 3. **Crop Water Use for Cowpea during 2015/2016 Dry Season**

Treatment	I_{100} RSM	I_{100} BPM	I_{100} NM	I_{75} RSM	I_{75} BPM	I_{75} NM	I_{50} RSM	I_{50} BPM	I_{50} NM
21/2/2016	5.0	6.0	9.0	6.0	5.0	5.0	5.0	5.0	6.0
25/2/2016	6.0	7.0	8.0	5.0	7.0	7.0	6.0	4.0	7.0
29/2/2016	6.0	8.0	16.0	6.0	8.0	7.0	7.0	5.0	6.0
03/3/2016	9.0	8.0	16.0	6.0	12.0	6.0	6.0	7.0	7.0
07/3/2016	10.0	9.0	17.0	6.0	12.0	7.0	7.0	6.0	7.0
11/3/2016	11.0	9.0	18.0	7.0	11.0	9.0	8.0	6.0	10.0
16/3/2016	11.0	13.0	20.0	8.0	12.0	10.0	13.0	11.0	10.0
28/3/2016	11.5	14.0	22.0	8.0	11.0	13.0	19.0	15.0	17.0
31/3/2016	11.8	14.0	20.0	7.0	12.0	14.0	15.0	15.0	15.0
04/4/2016	16.0	15.0	14.0	19.0	8.0	15.0	7.0	14.0	20.0
08/4/2016	16.2	10.0	20.0	10.0	9.0	15.0	8.0	14.0	16.0
12/4/2016	15.0	9.0	19.0	14.0	7.0	16.0	7.0	13.0	16.0
16/4/2016	15.0	5.0	9.0	15.0	8.0	17.0	6.0	8.0	15.0
20/4/2016	10.0	6.0	9.0	7.0	6.0	19.0	4.0	7.0	12.0
24/4/2016	9.0	6.0	7.0	5.0	6.0	10.0	5.0	5.0	11.0
28/4/2016	7.0	5.0	6.0	7.0	6.0	8.0	4.0	4.0	10.0
02/5/2016	5.0	5.0	5.0	5.0	4.5	8.0	5.0	5.0	5.0
Total	**179.5**	**155**	**242**	**148**	**149.5**	**152**	**117**	**120**	**135**

It can be noticed that the irrigation water applied and the seasonal water use decreased with an increase in deficit irrigation. The pattern of decrease in water use as a result of deficit irrigation was expected since deficit irrigation reduces the amount of water available in the soil for the plant to use. The highest irrigation water applied under irrigation treatment was at 100% SMD with 311.15 mm followed by 75%SMD with 199.8 mm then 50% ETo with 168.6 mm. However, the seasonal water use was significantly higher at 100% soil moisture depletion with 242 mm compared to the seasonal water use at 75% SMD and 50%SMD. In general, irrigation water applied and seasonal water use was found to decrease with a decrease in % of soil moisture depletion from 100% to 50%. However, with the use of different mulch materials, both the irrigation water applied and the seasonal water use recorded have high values at NM with 311.15 mm and 242.55 mm, while RSM and BPM were found to be similar. Mulching with rice straw and black polyethylene recorded significantly lower values of irrigation water applied and seasonal water use for cowpea compared to the no mulch treatment. This is expected as mulching helps to conserve moisture for crop use.

3.2 Crop Coefficient

The trend of crop factors for cowpea during the different phonological stages at full irrigation treatment is presented in Table 4. The Kc value shows a curve that peaks during the flowering/podding (midseason) of the crop. The Kc values for emergence (initial stage), Vegetative, Mid-season (flowering and pod formation), and senescence (late season) were 0.37, 0.9, 0.96, and 0.45 for no-mulch condition. Declining Kc values during the maturity stage might be due to reduced sensitivity of the stomata as leaves begin to senescence (Fraust, 1989). The Kc values obtained show that the highest water requirement occurs at the flowering and pod formation (midseason) stage.

In more elaborate form, the Kc values for RSM ranged from 0.3 - 0.8 for initial stage, 0.79 - 0.94 for development stage, 0.80 - 0.94 for mid-season and 0.43 - 0.91 for late season. For BPM the value ranges from 0.28 - 0.58 for initial stage, 0.82-0.94 for development stage, 0.88 - 0.96 for mid-season and 0.38 - 0.76 for late season. For NM the value ranges from 0.37 -1.2 for initial stage, 0.9 -1.09 for development stage, 0.96 - 1.09 for mid-season and 0.45 – 1.02 for late season. The Food and Agricultural Organization (FAO 1977) reported an estimate of Kc for different development stages of cowpea as 0.4 for the initial stage, 0.4, 1 and 1.5.

For the development stage, 1.05 for the mid-stage and 0.90 late seasons stage which is in the raofwiofhe Kc values estimated in this research. Also, the Kc value obtained is similar to the value obtained by Aboamera (2010) as 0.696, 0.651,0.673, and 0.60 for the initial, development, mid-season, and harvesting stage respectively with the full irrigation (100% of SMD). The reason in the Kc values at the mid-season stage is lower could be attributed to the low-temperature range, inherent variability in crop characteristics at the growth stage, and the fertilizer application that was not done as when due.

Table 4. ETo, ETa and Kc for the Growth Stages for Cowpea In the 2015/2016 Season

Treatment label	Initial stage			Development stage			Flowering/podding stage			Harvesting stage		
	ETo	ETa	Kc	ETo	ETa	Kc	ETo	ETa	Kc	ETo	ETa	Kc
I_{100}RSM	5.6	2.3	0.4	5.5	2.3	0.41	7.0	4.1	0.59	7.0	2.8	0.4
I_{100}BPM	5.6	2.2	0.4	5.5	3.3	0.61	7.0	2.6	0.37	7.0	2.0	0.3
I_{100}NM	5.6	4.0	0.7	5.5	5.3	0.97	7.0	4.3	0.62	7.0	2.6	0.4
I_{75}RSM	5.6	1.7	0.3	5.5	2.0	0.36	7.0	3.9	0.55	7.0	2.2	0.3
I_{75}BPM	5.6	2.6	0.5	5.5	3.1	0.56	7.0	2.1	0.31	7.0	2.1	0.3
I_{75}NM	5.6	1.9	0.4	5.5	3.7	0.68	7.0	4.2	0.60	7.0	4.1	0.5
I_{50}RSM	5.6	1.9	0.3	5.5	3.67	0.67	7.0	1.9	0.27	7.0	1.6	0.2
I_{50}BPM	5.6	1.6	0.3	5.5	3.13	0.57	7.0	3.3	0.47	7.0	2.3	0.3
I_{50}NM	5.6	2.0	0.4	5.5	3.90	0.70	7.0	4.5	0.64	7.0	3. 5	0.5

Table 5. Cumulative Evapotranspiration during the Growth Stages

Treatment label	Cumulative evapotranspiration (ETa) for growth stages (mm)				Seasonal total (mm)
	Initial (0-21 DAP)	Development (22-37 DAP)	Flowering/Podding (38-53 DAP)	Harvesting (54-65 DAP)	60-65 DAP
I_{100}RSM	34	48	62	31	175^{bc}
I_{100}BPM	40	47	42	20	149^{c}
I_{100}NM	63	79	70	23	235^{a}
I_{75}RSM	36	30	53	22	141^{de}
I_{75}BPM	34	48	44	18	144^{d}
I_{75}NM	40	51	53	43	187^{b}
I_{50}RSM	29	55	30	18	124^{fg}
I_{50}BPM	21	37	39	23	120^{fg}
I_{50}NM	27	41	45	22	135^{f}

Note**: Means followed by the same letter(s), in a column of any treatment group are not significantly different at p < 5 %. Where I_{100}, I_{75}, I_{50} are 100, 75, and 50% of soil moisture deficit respectively. RSM = rice straw mulch, BPM = Black polythene mulch, NM = No mulch.** Statistically test the significant difference between the values of the seasonal total for all the treatments.

3.3 The crop yield response factor

Figures 2-4 show the yield response factors (Ky) for NM, RSM, and BPM treatments, respectively obtained by plotting the data of the relative yields and relative seasonal crop water use of the treatment. The crop response Ky values were obtained as 0.83, 0.83 and 0.79.for the NM, RSM and BPM, respectively.

The coefficient of determination (r^2) for black polythene relationship was good (>0.75) while for that of rice straw and no-mulch were average at 0.57 and 0.58, respectively. According to Doorenbos and Kassam (1979), Ky <1.0 indicates that the decrease in yield is proportionally less with increase in water deficit, while yield decrease is proportionally greater when y>1.0.

The results of this study show that with mulch, the decrease in yield of the cowpea crop were proportionally less with increase in moisture deficit. It is however, noticed that the Ky values of the no-mulch treatment was higher than the mulched treatment by about 13.8 to 17.73%, which implies that the proportional decrease in yield under the no mulch treatment was much higher than the mulched treatment this may be due to effect of mulch material used which alleviated the effect of water stress.

Generally, higher Ky values indicate that the crop will have a greater yield loss when the crop water requirements are not met. This result indicated less impact of soil-water stress treatment on the cowpea yield.

The yield response factor (Ky) for cowpea in Samaru was found to be 0.783 for the growing season in this study.

Table 6. Computed Yield Response Factor

Treatment	Ya	Ym	ETa	ETm	Ya/Ym	ETa/ETm	1- (Ya/Ym)	1- (ETa/ETm)
I_{100} NM	1425.5	1425.5	242	242.33	1	1	0	0
I_{100} RSM	1428.6	1428.6	179.5	179.53	1	1	0	0
I_{100} BPM	1520.6	1520.6	155.5	155.54	1	1	0	0
I_{75}NM	1362		152		0.851	0.628	0.149	0.372
I_{75}RSM	1397.8		148		0.814	0.955	0.186	0.045
I_{75}BPM	1499.8		149		0.960	0.833	0.040	0.167
I_{50}NM	800.1		135		0.705	0.478	0.294	0.522
I_{50}RSM	978.4		117		0.774	0.755	0.226	0.245
I_{50} BPM	1103.3		120		0.733	0.669	0.267	0.331

Ym = 1425.5 Kg/ha, 1428.6 Kg/ha, 1520.6 Kg/ha corresponding to NM, RSM and BPM respectively at full irrigation; ETm = 242.33, 179.53, 155.54 for NM, RSM and BPM respectively.

3.4 Seed Yield -Seasonal Water Applied Relationship for the Cowpea Crop

Irrigation water applied throughout the irrigation season shows a linear response to yield however, yield began to decline at 200 mm depth of application this indicate additional water applied will not only unprofitable but will cause harm to the crop environment.

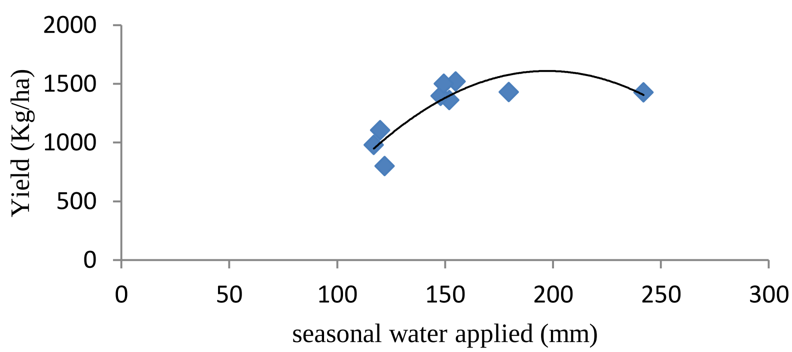

Fig 1. Seed yield -seasonal water application relationship

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